Making meaning: developing an understanding of form in distance design education

Conference or Workshop Item

Miquel Prats and Steve Garner
m.prats@open.ac.uk

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Abstract
Design education throughout the world provides students with a variety of experiences that help them develop an understanding of form and shape. The conventional model of such education requires students to participate in studio and workshop-based projects to develop skills through the creation of models and prototypes. However, with the increase in distance education worldwide we need to explore new ways for students to create and manipulate form remotely. This paper presents new work at the Open University, UK which set out to engage design students in form-making from a distance. Participants were given access to technical and design support that took rough sketches of chair designs and converted these into tangible scale models which were mailed back to the students. Several cycles of this activity generated data on how such supported modelling activity stimulated students' creative ability, design knowledge and motivation. This paper proposes new priorities for distance design education.

Keywords
Distance Learning, Design Education, Physical Models, Form.

1 Introduction
Design education aims to develop in students the necessary skills and knowledge for design problem solving. The characteristics of design problems have been widely and variously discussed over the past five decades but two characteristics stand out as significant; design problems display complexity and they contain elements of uncertainty such as missing or ambiguous information. As a consequence the strategies for design education from school age to undergraduate level must go beyond the application of set procedures and develop in students a cognitive capacity for integrating creative problem finding with creative problem solving. Donald Schön [1] proposed that such integration requires an active rather than a passive approach, reinforcing the notion of 'learning while doing' which lies at the core of the atelier-style of design education in our universities and colleges. Schön's 'reflection-in-action', has proved influential and remains so as new models of distance design education emerge in universities worldwide. Schön asserts that creative reflection requires a stimulus to trigger innovative thinking. Traditionally design students have been encouraged to generate a wide range of representations in their design project work and these have partly functioned as trigger devices to support the type of reflection-in-action identified by Schön. The making of representations such as drawings and three-dimensional models are particularly valuable to students as they grapple with the creation and evaluation of form and shape in design. Some of this representation-making activity is careful and measured while at other times it can be fast and loose depending on its function for the designer [2] and [3].

While there is great variety in types of design representations, physical models can raise design issues in ways that drawings and diagrams often cannot [4]. It's for this reason that the making of physical models remains an essential part of the education process in some design disciplines such as product design, sculpture and architecture. Even disciplines such as graphic communication and interaction design recognise the value of three-dimensional constructions as trigger devices in creative thinking. There are many different types of physical models each with different purposes [5]. For example, prototypes provide an effective means to test or communicate design ideas, especially in the later stages of development [6]. In contrast, quick lash-ups or form models can be extremely useful in the early conceptual stage of a design task. They can be useful for testing design specifications or for evaluating a potential appearance [7]. But physical modelling isn't just about externalising ideas. Perhaps more importantly physical models help designers learn about the problems they are trying to solve.

It has been argued that the ability to engage students with rapid and physical feedback during their design process is an essential ingredient in the acquisition of confidence and professional creativity [8]. As a consequence, the conventional model of such education requires students to participate face-to-face in studio and workshop-based projects to develop skills through the creation of models and prototypes. However, with the increase in distance education worldwide we need to explore new ways for students to create and manipulate form remotely - perhaps from their homes or workplaces.

According to Welsh [9] universities and other institutions are increasingly seeking to offer an online learning experience to potential customers. Partly this is seen as an opportunity for reducing costs but there is now much accumulated evidence that 'e-learning' can deliver high quality education in the arts, sciences and humanities and open up new student markets. Bohemia's [10] on-line delivery of the Design Management course, for example, provided cost savings, but more importantly, not only the aims of the course were achieved but also assisted students to develop distance communication and virtual teamwork skills. There is certainly a growing demand for education and training that can be taken part-time and which doesn't require the student to travel. But can design education exploit an e-learning approach? Can distance design education really go beyond teaching students 'about' design and involve them in learning 'through' design? The Open University has offered distance design education since the 1970s but only recently has it been possible to recreate some of the characteristics of a typical studio-based design course. New technologies now allow students to share design ideas and conduct online group work. Computer-aided design (CAD) is readily available and facilitates new types of digital modelling. But the making of three-dimensional models has always proved a difficult component to support. Partly the problem is that students don't have access to the types of tools and materials commonly found in face-to-face design education. Neither do they have access to teaching and technical staff for guidance, or their peers for collaboration and comparison as they develop their skills of making. If the making of three-dimensional representations of form are vital to the sort of reflection-in-action processes described by Schön then universities that seek to offer design education need to find ways to support this. With this in mind a short piece of research was conducted by the authors at the Open University early in 2009.

2 Description of the study

The Open University project took place over four months and engaged volunteer second-level undergraduate students in form-making from a distance. In its planning it took McCullough's [11] premise that design students studying via a distance learning approach must be able to engage with physical models as well as with digital tools and outputs. It was informed both by generic guidance on e-Learning, e.g. [12] and recent design initiatives such as the remote rapid prototyping laboratory set up at Tennessee Tech University in the US [13]. This particular facility allows students to generate three-dimensional models from a remote location.

This project sought to gain an understanding of the value to design students of making physical models. In particular it sought to explore the value and feasibility of providing a rapid prototyping service from the 'FabLab' to novice students without computer-aided design and rapid prototyping skills. All the students engaged with the project from their own remote locations. The Rapid

Fabrication Laboratory (FabLab) was set up within The Design Group at the Open University in 2006. It offers a range of equipment for rapid prototyping including a laser cutter, Fused Deposition Modelling (FDM) 3D printer and 3D laser scanner among many others. Other more traditional subtractive processes such as milling are also available. These tools offer engineers and designers quick and easy ways to iterate between digital representations and physical representations.

Students on the Open University course 'Design and Designing' were invited to take part in the study. This is a 60 credit module and while their skills and experience of design differed all could be considered as novice or inexperienced design students. One participant had completed a graphic design course and one a course in art and design. For some this was their first Open University course. Of the seven students who originally volunteered, two had to withdraw from the study during the first week for personal reasons so five participants completed the study. Four were based in the UK and one in Germany. Students were mature, that is, aged over 25, male and female.

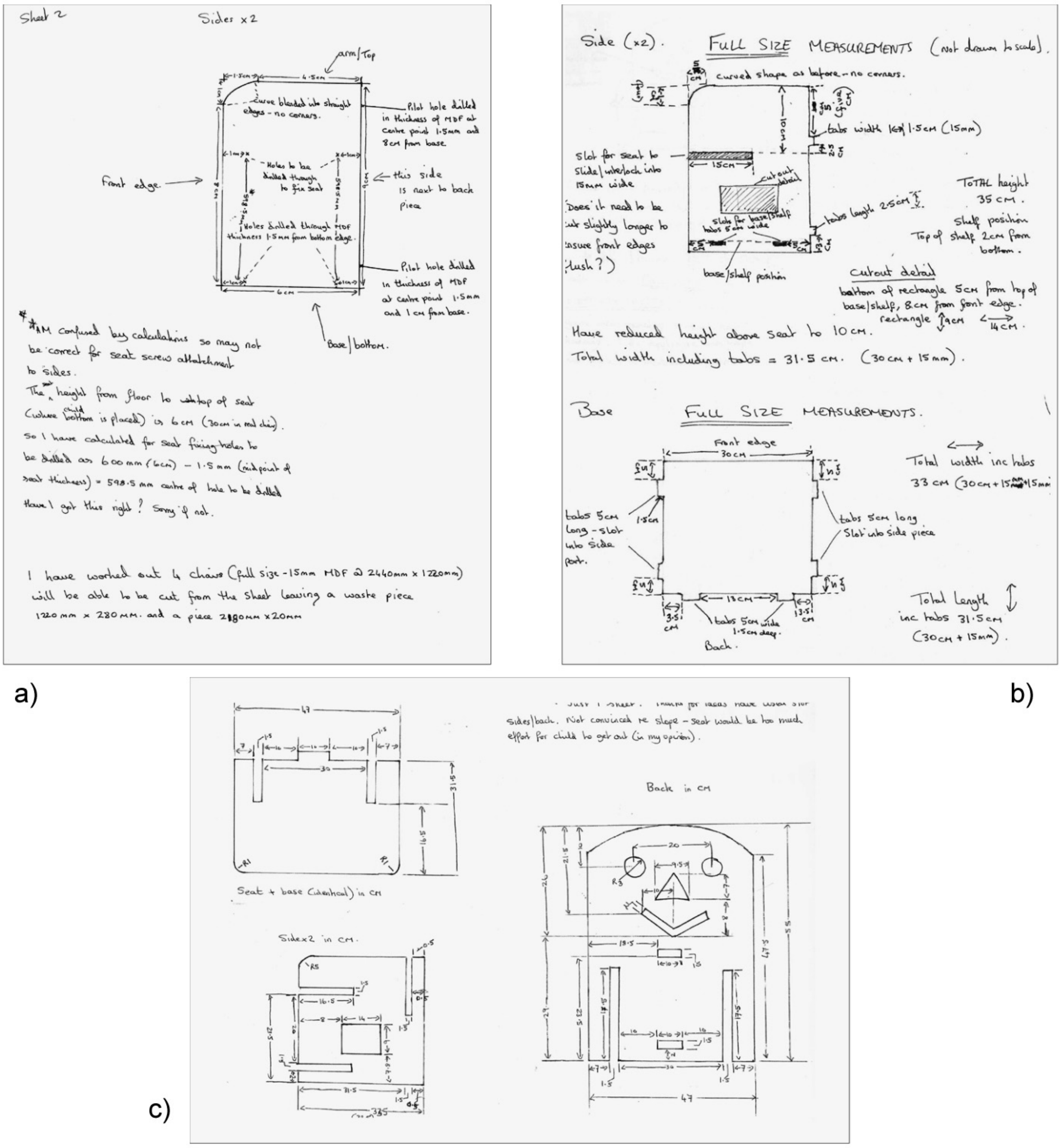
The chosen context for the study was chair design using flat sheet material. The reason for this is that it was very similar to the context for an assignment in Design and Designing taking place at the same time. A number of support materials on chair design had previously been sent to all the participants through the normal course mailings. Using this context was highly motivating to all participants but they were prohibited from gaining an unfair advantage over their peers by submitting their models for assessment. However it did mean the students could tap into research and development with which they were already familiar and they could generate ideas and variations more quickly than if they had been given an entirely new context. The brief asked students to design a chair for children to be made in medium density fibreboard (MDF) which could be sold flat-pack and assembled at home. It was required that the chair designs could be assembled without glue and with the minimum of fixings such as screws or bolts. Students were also limited to one thickness of MDF, 15mm. In this way it was possible to support the design thinking of the participants by providing them with models of their design ideas. These were fifth-scale models and the component parts were cut out from 3mm thick MDF using a laser cutter. This machine cuts a variety of flat materials such as wood, plastic, and fabric. It works by directing a high powered laser beam onto the material which it either cuts or engraves, depending on how the machine has been set up. The laser cutter receives the cutting or engraving specification from a computer file and can make pieces of any shape in high precision in a matter of minutes.

Participant students were permitted to submit any form of sketch representation of their initial chair design and this was modelled for them in the 3mm MDF using a laser cutter. Since it was important to the study to support the participants at whatever level of design skill they possessed it meant that the tutor received design concepts in a variety of levels of detail. In this study, the tutor, which is one of the authors of this paper, was the person in charge to develop the CAD drawings and physical models. Typically participants supplied hand-drawn sketches that required careful interrogation in order to interpret what the student intended. The tutor produced a new CAD drawing that, as far as possible, matched the instruction given in the sketch. This CAD file was used to control the laser cutter and generate the component parts. These were then posted to participants to assemble. After evaluation of the constructed model participants were asked to communicate with the tutor about the changes they wanted to make and once again annotated sketches were used to communicate their intentions. Some students chose to attach scans of their sketches to email in order to speed up the communication process. Then the tutor made a new scale model according to instructions and posted it back to the student. The manufacture of each set of component parts could be easily completed within one day and each cycle could be completed in 4-5 days. Participants were allowed a maximum of four cycles of making and changing.

3 The conduct of the study

All participants began the task by developing their design ideas using pen or pencil and paper. Two students supplemented their drawings with simple cardboard models of their initial chair design. Both said that since their perspective drawing skills were poor they felt the models helped them communicate intention. One pointed out that the model also assisted her to test the stability of the chair.

Students sent their annotated drawings (and in the cases above, images of their cardboard models) to the tutor via mail, or email if work could be scanned. Fig. 1 shows some examples of drawings from this first cycle a), second cycle b), and fourth cycle c). The submissions reveal the attempts to capture sufficient information while wrestling with conventions such as layout. Dimensioning, for example, reveals missing or conflicting dimensions, or mixing values between centimetres and millimetres. In addition, some students included extensive notes when they could not express their ideas through drawings alone as this student that pointed out 'I have no idea how to specify that so I went with what I could communicate with some certainty'. Despite this, it was possible to understand the design intentions of all students and, with little effort, the components of the scale models of the chairs were redrawn into the computer by the tutor. Then, these were cut out with the laser cutter and sent back to students via the post service.



a) b) c)

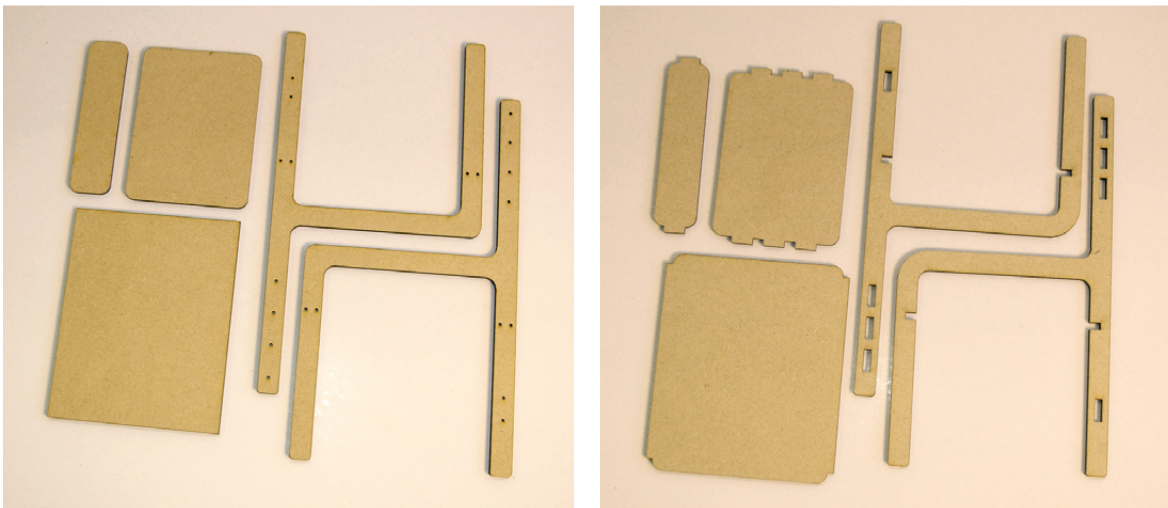
Fig. 1. Sketch pages from the first a), second b), and fourth cycle c) of one participant.

When the dimensions in the drawings from the students had errors or miscalculations the pieces were cut as instructed, even if they did not fit together correctly. Thus, students had the opportunity to get physical feedback on their mistakes. Additionally, their drawings were returned to them with corrections and suggestions on how to improve their graphic communication.
The drawings in Fig. 1 provide an illustration of the improvement of students' skills in communicating their ideas. The sheets a) and b) in Fig. 1 contain some initial drawings with several notes which make the task of redrawing the pieces into the computer laborious; the drawings made in the last iteration of the study, sheet c), are more comprehensive and include much less annotation.

The first design concepts submitted frequently failed to adequately address the requirements laid down in the design brief. These included the requirement that the chair should be assembled without glue and minimum of fixings. Feedback from the students suggest that they were not avoiding the requirement but they were not able to creatively address it. One student commented 'I am coming up blank on fixings that could be used that don't require holes to be drilled. And I am aware that glue is not an option'. For example, some students included pre-drilled screw holes in some components. Once they had received feedback on assembly methods these were replaced by superior design features such as mortise-and-tenon joints or finger joints. In one case two sets of pieces – pieces with pre-drilled holes and a jointed set – were sent to the maker so they had tangible feedback on different design and assembly methods. Fig. 2 shows this example of two sets of pieces.

4 Making meaning through supported modelling

As noted in the introduction to this paper, the making of models is a normal and everyday activity in face-to-face design education. Academic and technical support is made available through a programme of studio and workshop experiences that gradually allow students to develop their skills and knowledge of modelling in design. Even by the end of the first year of a typical undergraduate design programme students will be equipped to make a wide range of models ranging from the briefest of sketch models to highly finished form models or prototypes. However, supporting modelmaking as a part of distance design education has particular and significant problems. Students are unlikely to have access to tools, materials and machines for modelmaking and there are major health and safety issues to getting students to engage in shaping and forming even basic materials such as cardboard.
This study has documented a rather time-consuming process of technical support and it may be reasonable to ask whether the investment was worth the outputs of a few scale models. To answer this, and to further our understanding of why modelling forms a key element in future distance design education we must return to 'why' students need to model.



a) b)

Fig. 2. a) pieces as instructed by the student and b) suggested pieces using mortise-and-tenon joints and finger joints.

Clearly the three-dimensional scale models of the chairs provide very clear proposals. They provide very clear communication of intention – probably as good if not better than any drawings of the chairs. But communication is only one function of such modelling. A far more significant function is the ability for three dimensional models to engage the maker in a private creative dialogue. The making of even quite rough and quick models allows the designer to assess and extend their thinking, to see relationships, to turn the ideas around in their head as well as in their hands. This is particularly important for novice designers where cognitive modelling – that ability for turning over ideas in the mind – is not yet developed. In fact, the making of tangible models might be the very stimulus needed to develop skills of mental modelling.
So making tangible models is not about externalising ideas, although this is one valuable function. More importantly it assists novice designers to develop notions of form and shape. It allows them to understand relationships between forms through the senses of touch and sight. It is a vital stage in developing a more mature capacity to hold, rotate and join shapes in the mind and as such it forms a vital link in developing skills with a wide range of digital design tools such as software for the creation of structure and surfaces on artefacts.

Any model of distance design education cannot afford to ignore the development of these competencies. The feedback from the participants in this study reveal how physical models motivated students' to develop an understanding of the principles of form in design and stimulated their creative thinking. Perhaps most importantly, it engaged people in matters of design form before they developed the skills to create and manufacture their own design form. The findings have

Fig. 3. Development of design concepts.

implications for the future of face-to-face as well as distance design education because we have traditionally preferred to develop technical skills with tools and materials at the expense of developing cognitive skills associated with reflection, integration and evaluation.
In this study the students were relieved of the technical skills (skills that they may learn in more advanced design courses) but still benefited from seeing their ideas emerge through three-dimensional form.
Sandler [14] asserts that the choice of algorithm for solving a mathematical problem is like the choice of a physical model in engineering. In both cases students need to understand why they need to ask the right questions in their modelling strategy. Of course students can learn about form through other means, e.g. drawings or computational programs [15], but using physical models engages the mind with visual and tactile stimulation. They offer opportunities for what Schön characterised as reflection-in-action – a rich activity that is both contemplative and creative.
The feedback from the study also reveals the power for models to increase the confidence of novice designers. Modelling prompted participants to explore more ambitious ideas. As one student stated 'I was nervous at the start and very conservative in design but with the models I gained confidence and became excited waiting for my model to come and eager to make design improvements'.
The conversion of students' rough drawings into a tangible chair motivated them to explore their ideas further. Discovery and understanding of new assembly techniques contributed to students' desire to improve their design ideas; as one student pointed out at the end of the study 'I have enjoyed the whole learning experience, especially how the joining can limit design or trigger new ideas'. Also physical models assisted students to realistically reflect upon their ideas and motivate them in making functional and aesthetic adjustments on their designs. The progression of the design concepts in Fig. 3 illustrates evolution of jointing and assembly. With new confidence in a concept or detail so ambition increases.

5 Conclusions

It's clear that the traditional model of face-to-face design education with its studios, workshops and display areas is an expensive model to sustain. It seems equally clear that all institutions offering design education at undergraduate level will adopt some aspects of distance learning even if these are intended only to support and enhance a predominantly face-to-face experience.
For many design students, even novice ones, the making of physical models is a natural and spontaneous act that they take to enthusiastically. Any requirement to have to develop digital or machine skills may act to suppress this vital enthusiasm for making and modelling. This work reveals a successful engagement with modelling before any teaching of the traditional skills and knowledge needed for the safe modelling of design ideas.
This work suggests that giving students access to three-dimensional models is vital to their design learning. This is not because such models help students communicate their proposals for form and shape but that they assist students in the very act of thinking about form and shape. This thinking skill, this cognitive modelling, is one of the core building blocks in design education. It has obvious application in those design disciplines concerned with three dimensional outputs such as transport design or architecture but it also has value in extending the cognitive skills of designers looking to build a career in graphic communication or interaction design.
In the work presented here participants were given access to technical and design support that took rough sketches of chair designs and converted these to tangible scale models which were posted back to the students. Several cycles of this activity revealed an important value for this type of support – particularly for novice design students
Of course there are negative outcomes too. Interpreting and transferring sketch drawings from paper to CAD is time consuming for the person supporting the students. However it is possible that this might make a good context for peer support – perhaps level 2 students supporting level 1 novices. If, as this paper suggests, design novices can cultivate an understanding of design form through distance collaborative interaction then a world of new commercial possibilities opens up for the involvement of users in collaborative product innovation. Design organisations could educate their customers and then integrate their new competence in the co-creation of consumer products, vehicles, fashion items, perhaps even buildings. It would be a radically new way of making meaning. The work presented here is both curriculum development and research. It illuminates an agenda for research and as such there is much still to do.

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Miquel Prats,
Steve Garner
The Design Group,
The Open University,
Milton Keynes, UK